

Social and Biotechnological Studies of Wild Edible Mushrooms in Mexico, with Emphasis in the Izta-Popo and Zoquiapan National Parks

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Abstract: In Mexico, there is an ancestral traditional knowledge related to wild edible mushrooms. Currently, more than 200 species of wild mushrooms are consumed in the country and more than 100 are sold in traditional markets. In this paper, first, the levels of commercialization of wild edible mushrooms in Mexico are analyzed. Then, the species sold in the area of influence of the Izta-Popo and Zoquiapan National Parks, located in Central Mexico and their phenological patterns are presented. Finally, an evaluation of the effect of pine growth under greenhouse conditions and field survival as a result of inoculation with three ectomycorrhizal edible fungi is presented. In the region, more than 100 names are used to denote edible species. The highest numbers of fungal species were recorded in July and August. Ground pileus have been used as a successful source of ectomycorrhizal inoculum. Until now, the best results have been obtained with species of *Hebeloma*, *Laccaria* and *Suillus* under greenhouse conditions. Evident increases in survival of plants inoculated with a mixture of these species have been recorded under field conditions compared with non-inoculated plants.

Key words: Phenological patterns; Ectomycorrhizal fungi; Inoculation; *Pinus*; Field survival

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Introduction

Mexico holds large biological and cultural diversities. It has been considered a mega diverse country, possessing, together with 12 other countries, 80% of the planet's biodiversity and alone has around 30 000 plant species and 45 vegetation types (Conabio, 1998). Some groups of organisms, whose biological diversity in the country is huge, are especially important worldwide. For example, the country is first in the number of species of ectomycorrhizal (ECM) trees of major forest importance, such as *Pinus* (with 72 taxa) (Perry, 1991) and *Quercus* with 150 species (Valencia, 2004). As a result of this peculiar combination of great biological and cultural diversity (including more than 50 ethnic groups), there is profound traditional knowledge of wild fungi. The use of wild edible mushrooms in Mexico goes back to pre-Hispanic times, as evidenced by linguistic and ethnological tests. In the country more than 200 wild mushrooms are consumed (Villarreal and

Pérez-Moreno, 1989), and more 1000 common names in the different native languages are used to denote these edible mushrooms species (Guzmán, 1997). Considering the above scenario, a project that includes taxonomic, social, ecological and biotechnological aspects of wild edible mushrooms has been carried out currently in the Izta-Popo and Zoquiapan National Parks and its surrounding areas, in Central Mexico, funded by the Mexican government (through the project SEMARNAT-CONACYT 2004 - 01 - 45) from 2005 to 2008. This paper presents some social and biotechnological information of the wild edible mushrooms of Mexico, including: i) a summary of the levels of commercialization of wild edible mushrooms in Mexico; ii) a phenological assessment of 68 wild edible mushrooms in nine markets in Central Mexico; and iii) an evaluation of the influence of inoculation with three edible ECM mushrooms on pine growth under greenhouse conditions and survival of inoculated plants under field conditions.

Materials and Methods

Studied area The Izta Popo and Zoquiapan National Parks are located in Central Mexico, between $18^{\circ}59'$ and $19^{\circ}16'25''$ N and $98^{\circ}34'54''$ and $98^{\circ}16'25''$ W. The area is covered mainly with coniferous and broad-leaf forests, including: i) pine forests (mainly *Pinus hartwegii* and *P. pseudostrobus*) from 2 500 to 4 000 m altitude; ii) fir forests (*Abies religiosa*) from 2 500 to 3 500 m altitude; iii) mixed forests including ecotones of *Pinus* spp., *Alnus* spp. and *Quercus* spp. from 2 500 to 3 500 m altitude, and iv) subtropical moist montane forests from 2 500 to 2 800 m altitude (Izta Popo National Park, 2007). These kinds of forests favor the development and diversity of wild edible mushrooms. The park includes 22 municipalities and their area of environmental and social influence affects three Mexican States: Mexico, Puebla and Morelos, and also Mexico City. First gatherers, hunters and fishers arrived to the area, at least, 22 000 years ago as shown by archaeological evidence. Collection of wild edible mushrooms in the region is therefore ancestral and definitely started from Prehispanic times in native groups of náhuatl origin.

Phenological assessment To register the seasonal variations of the species of wild edible mushrooms that are marketed in the area of influence of the Izta-Popo Zoquiapan National Park, 50 visits were made to 9 markets, during 2006. The sampled markets of this area are located in the state of Mexico and Mexico City. Identification of wild edible mushrooms was carried out by using routine mycological techniques and both macro and micromorphological characteristics of the mushrooms. Authorities of fungal species are those recognized in Index Fungorum (2008).

Biotechnological studies In the inoculation experiments two pine species and three edible ECM mushrooms were studied. Mushrooms were chosen among species commonly sold in the local markets. In the preparation of ECM inoculum, pileus of *Hebeloma mesophaeum* (Pers.) Qué. and *Laccaria bicolor* (Maire) P. D. Orton, and hymenia of *Suillus pseudobrevipes* A. H. Sm & Thiers were used. These structures were dehydrated below 36°C , then ground and

filtrated by a 1 mm mesh to obtain uniform particle size. Seeds were planted in black plastic 140 cm^3 tubes that contained a mixture of sawdust-sand-soil in a 2:2:1 proportion. Each plant was inoculated with at least 10^7 to 10^8 spores. Two inoculations were performed to increase the probability of colonization. ECM inoculum was placed in holes made on the surface of the substrates contained in the tubes. The plants were irrigated with distilled water for 240 days when they are necessary. Shoot and root dry weights were recorded 240 days after planting with plants that were previously dried at 80°C . Shoot and root total N and P of each plant were calculated following Bremner (1965) and Olsen *et al.* (1954), respectively. The percentages of ECM colonization were calculated for all plants. Additionally, morphological characterization of the morphotypes found was conducted (Agerer, 1991) to assess the presence of the mushrooms used as inoculum. The data obtained for different variables were subjected to an analysis of variance and the Tukey test of comparison of means ($\alpha = 0.05$) (SAS Institute, 1999). Survival of inoculated and non-inoculated plants was evaluated under field conditions in a parallel set of *Pinus greggii* plants kept under greenhouse conditions for 12 months. Evaluation of plant survival was carried out 92, 112, 170 and 262 days after seedling transplanting. The selected site lacked forest during the last 30 years.

Results

Commercial wild edible mushrooms in Mexico

The use and commercialization of wild edible mushrooms is very common in Central and Southern Mexico and in general terms, it can be grouped in four categories:

1) Self-consumption: A large number of wild edible mushrooms have a greater value than exchange value and therefore they are self-consumed by native mushroom collectors. This category includes: i) species with a short shelf life; ii) species with usual low natural productions; and iii) species highly valued by local collectors for their special taste. Occasionally some species belonging to this category are sold in mar-

kets as well, for example when natural productions are much more than usual. Around 100 species are grouped in this category.

2) Direct commercialization by native collectors: Frequently, mainly in the rural areas of the country, native collectors directly sell mushrooms to consumers, without brokers or middle businessmen. In these areas, collectors usually travel very long distances on foot trying to gather the highest possible amounts of mushrooms. Mushroom collection can start very early in the morning, around 4:00 a.m. and finish around 5:00 p.m., this is more than 12 hours of work daily. In these cases, there is a low-scale commercialization and frequently each collector commercializes no more than 20 kilograms at a time. The commercialization is usually accomplished with mixtures of species in pileus rather than in complete kilograms. In these kinds of markets, prices are not fixed because bargain is a very common practice. Even when mushroom collection is a familiar activity, sellers in these kinds of markets are usually women, maybe because of their great capabilities to negotiate prices. More than 100 species are commercialized in Mexican traditional markets.

3) Commercialization through intermediaries. In large cities, such as Mexico City, sale of wild mushrooms is mainly through intermediaries. Wild mushrooms are transported from areas where they are bought from native gatherers to wholesale markets by vehicles. It is very frequent that the chain is made up of three or four intermediaries. Price bargaining is frequent that at each change of hands. Sales in these large markets in Mexico City, for example, take place at different times. In "Central de Abastos" market sale begins at 4:00 a.m. and ends around 7:00 a.m., while in "La Merced" market it begins around 6:00 a.m. and ends around 3:00 p.m. Some of the large markets are truly regional collection centers given the simultaneous commercialization of wild mushrooms from different parts of the country. Weekly quantities of commercialized wild mushrooms in these markets are measured in tons.

4) Exportation to international markets. A reduced number of ECM wild mushrooms species of Mexico is exported to international markets, mainly to the

United States, several European countries and Japan. Among these, *Amanita caesarea* s.l., *Boletus edulis* s.l., *Morchella* spp., *Cantharellus cibarius* and *Tricholoma matsutake* are the principal species. Although there are admirable attempts, for example of the Mixe group of Oaxaca, the legal framework in general and the degree of social organization for wild edible mushrooms export from Mexico is quite incipient, as opposite to other countries with also great ancestral mycological tradition, like China. Frequently, most of the profits remain in the groups of intermediaries who buy commercially valuable wild edible mushrooms from local gatherers at very low prices and at the same time demand very high quality. The prices paid to the local gatherers vary conspicuously depending on the region and the degree of information to which the gatherers have. In general, prices paid to native collectors of mushrooms subject to exportation, are sadly established in the black market. Dozens of Tons of wild mushrooms are exported yearly from different parts of Mexico but because of the lack of strict legal regulation, exact data on the commercialization of the different species are not accurately known. However, the exportation of these wild edible mushrooms from Mexico, definitely has a commercial value, with great social importance for poor local communities where collection of wild edible mushrooms is usually carried out in every year.

Phenology of wild edible mushrooms

Three phenological patterns (Table 1), of those proposed for wild edible mushrooms of Mexico, were identified: i) 44% of the species presented a short early fructification pattern (May to August); ii) 31% of the species presented an early prolonged fructification pattern (July to December); and iii) 25% of the species presented a short fructifications in the middle of the season pattern (July to October). Most of the species were recorded in the middle of the rainy season, from July to August (Table 1). In the studied area, we recorded more than 100 common names used to denote wild edible mushrooms. However, in general terms, a conspicuous loss of mycological traditional knowledge is occurring in the area in part originated by: i) agricultural crisis; ii) influence of massive communication me-

dia; and iii) modification of familiar and social values . However, according to our observations there are some areas in the region , mainly in small towns , where native people still retain its traditional culture and subsistence pre-Hispanic practices, including collection and consumption of wild edible mushrooms .

Table 1 Phenological patterns of wild edible mushrooms commercialized in nine the markets in Central Mexico in 2006*

Pp	Species	Trophic group	Months															
			M		J		J		A		S		O		N		D	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a	<i>Agaricus campestris</i> Fr .	S	+	+	+													
a	<i>Amanita vaginata</i> var. <i>vaginata</i> (Bull .) Lam .	ECM				+	+	+	+									
a	<i>Armillaria mellea</i> (Vahl) P . Kumm .	S		+	+	+	+	+										
a	<i>Boletus clavipes</i> (Peck) Pilát & Dermek	ECM					+	+	+	+								
a	<i>B. luridus</i> Schaeff .	ECM			+													
a	<i>Retiboletus griseus</i> (Frost) Manfr . Binder & Bresinsky	ECM			+	+												
a	<i>Clavulina coralloides</i> (L .) J . Schr t .	ECM							+									
a	<i>Entoloma clypeatum</i> (L .) P . Kumm .	ECM						+		+								
a	<i>Flammulina velutipes</i> (Curtis) Singer	S			+													
a	<i>Gomphus floccosus</i> (Schwein .) Singer	ECM						+	+									
a	<i>Hebeloma alpinum</i> (J . Favre) Bruchet	ECM				+	+	+	+	+								
a	<i>H. leucosarx</i> P . D . Orton	ECM				+	+	+	+	+								
a	<i>H. mesophaeum</i> var. <i>mesophaeum</i> (Pers .) Qué l .	ECM				+	+	+	+	+								
a	<i>Hygrophoropsis aurantiaca</i> (Wulfen) Maire	S		+	+	+		+	+									
a	<i>Hygrophorus hypothejus</i> (Fr .) Fr .	ECM						+	+	+								
a	<i>Hypomyces lactifluorum</i> (Schwein .) Tul . & C . Tul .	P			+	+	+	+	+									
a	<i>H. macrosporus</i> Seaver	P			+	+												
a	<i>Lycoperdum pyriforme</i> Schaeff .	S								+								
a	<i>Pluteus cervinus</i> var. <i>cervinus</i> (Schaeff . ex: Fr .) Kum .	S							+	+								
a	<i>Ramaria stricta</i> var. <i>concolor</i> Corner	S			+	+	+	+	+	+								
a	<i>R. cystidiophora</i> (Kauffman) Corner	ECM ?							+	+								
a	<i>R. fennica</i> var. <i>fennica</i> (P . Karst .) Ricken	ECM ?							+	+								
a	<i>R. rubiginosa</i> Marr & D. E . Stuntz	ECM ?					+	+	+	+								
a	<i>Ramaria rubrievanescens</i> Marr & Stuntz	ECM ?					+	+	+	+								
a	<i>R. rubripermanens</i> Marr & D. E . Stuntz	ECM ?					+	+	+	+								
a	<i>R. sanguinea</i> (Pers .) Qué l .	ECM ?					+	+	+	+								
a	<i>R. stricta</i> (Pers .) Qué l .	S			+	+												
a	<i>Russula brevipes</i> Peck	ECM							+	+								
a	<i>R. olivacea</i> (Schaeff .) Fr .	ECM					+	+	+	+								
a	<i>Suillus pseudobrevipes</i> A . H . Sm . & Thiers	ECM			+	+												
b	<i>Gyromitra infula</i> (Schaeff .) Qué l .	ECM						+	+	+								
b	<i>Hygrophorus russula</i> (Schaeff .) Kauffman	ECM					+		+	+								
b	<i>Amanita crocea</i> (Qué l .) Singer	ECM							+									
b	<i>Ustilago maydis</i> (C . D .) Corda	P				+	+	+	+	+	+	+						
b	<i>Clavulina cinerea</i> f. <i>cinerea</i> (Bull .) J . Schr t .	ECM								+	+		+					
b	<i>C. cinerea</i> f. <i>sublilascens</i> (Bourdote & Galzin) Bon & Courtec .	ECM							+	+	+	+	+	+				
b	<i>Ampulloclitocybe clavipes</i> (Pers .) Redhead, Lutzoni, Moncalvo & Vilgalys	ECM						+	+	+	+							
b	<i>Helvella elastica</i> Bull .	ECM						+	+	+	+							
b	<i>Pseudocraterellus undulatus</i> (Pers . Rauschert)	ECM						+	+	+	+		+					
b	<i>Laccaria proximella</i> Singer	ECM							+	+	+	+						
b	<i>Lycoperdon perlatum</i> Pers .	ECM						+	+	+	+							
B	<i>Pleurotus cornucopiae</i> (Paulet) Rolland	S							+	+		+						
B	<i>Ramaria</i> aff. <i>gelatinosa</i> Holmsk .	ECM ?					+	+	+	+								
B	<i>R. holorubella</i> (G. F . Atk .) Corner	ECM ?					+	+	+	+	+	+						
B	<i>R. pallida</i> (Schaeff .) Ricken	ECM ?							+	+								
B	<i>R. rasilispora</i> Marr & D. E . Stuntz	ECM ?					+	+	+	+	+	+						
B	<i>Russula mexicana</i> Burl .	ECM							+	+	+							
c	<i>Amanita caesarea</i> (Scop .) Pers .	ECM		+	+	+	+	+	+	+	+							
c	<i>A. franchetii</i> (Boud .) Fayod	ECM			+	+	+	+	+	+	+	+	+	+				

Continue table 1

Pp	Species	Trophic group	Months														
			M		J		J		A		S		O		N		D
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	1
c	<i>A. fulva</i> (Schaeff .) Fr .	ECM				+	+	+	+	+	+	+	+				
c	<i>A. rubescens</i> var. <i>rubescens</i> Pers .	ECM			+	+	+	+	+	+	+	+	+				
c	<i>Boletus edulis</i> Bull .	ECM			+	+	+	+	+	+	+	+					
c	<i>B. pinophilus</i> Pilát & Dermek .	ECM		+	+	+	+	+	+	+	+	+					
c	<i>Cantharellus cibarius</i> var. <i>cibarius</i> Fr .	ECM		+	+	+	+	+	+	+	+		+	+	+	+	+
c	<i>Clitocybe gibba</i> (Pers .) P . Kumm .	ECM			+	+	+	+	+	+	+		+				
c	<i>Gymnopus dryophilus</i> (Bull .) Murrill	S		+	+	+				+			+				
c	<i>Helvella lacunosa</i> Afzel .	ECM						+	+	+	+		+		+	+	+
c	<i>Laccaria amethystina</i> Cooke	ECM					+	+	+	+	+	+	+	+	+		
c	<i>L. bicolor</i> (Maire) P.D . Orton	ECM					+	+	+	+	+	+	+	+	+	+	+
c	<i>L. laccata</i> (Scop .) Cooke	ECM		+	+	+	+	+	+	+	+	+	+	+	+	+	+
c	<i>L. proxima</i> (Boud .) Pat .	ECM			+	+	+	+	+	+	+	+	+	+	+	+	+
c	<i>Lactarius deliciosus</i> (L .) Gray	ECM			+	+	+	+	+	+	+		+				
c	<i>L. indigo</i> (Schwein .) Fr .	ECM			+	+	+		+				+				
c	<i>L. salmonicolor</i> R . Heim & Leclair	ECM			+	+	+	+	+	+	+		+				
c	<i>Lyophyllum decastes</i> (Fr .) Singer	ECM	+	+	+	+	+	+	+	+	+		+				
c	<i>Morchella esculenta</i> (L .) Pers .	ECM			+	+	+	+	+	+	+	+	+		+	+	+
c	<i>M. elata</i> Fr .	ECM			+	+	+	+	+	+	+	+	+		+		+
c	<i>Russula delica</i> Fr .	ECM			+	+	+	+	+	+	+	+					

* The studied markets were: i) in Mexico city: “ La Merced ”, “ Jamaica ” and “ Central de Abastos ”; ii) in the state of Mexico: “ Texcoco ”, “ Ozumba ”, “ Amecameca ”, “ Chalco ”, “ San Rafael ” and “ Colonia vila Camacho ” . Pp = Phenological patterns: a = species with short early fructification (May to August); b = species with short fructification in the middle of the season (July to October); c = species with early prolonged fructification (July-August-December) . Trophic group: S = saprobe; ECM = ectomycorrhizal; P = parasite . 1 = first fortnight of the month; 2 = second fortnight of the month

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In general terms, plant inoculation with any of the three evaluated ECM edible mushrooms produced a significant increase in terms of dry weight of the shoot and roots compared with non-inoculated plants . A similar trend was observed in the case of N and P contents . The highest beneficial effect was produced in the case of plants inoculated with *Hebeloma mesophaeum* (Table 2) . There was no evidence of synergistic or competitive effect when simultaneous inoculation with the three ECM fungi was carried out . The percentages of total ECM colonization were 58, 57, 76 and 59% for *P. greggii* and 84, 77, 89 and 63% for *P. pseudostrobis*, in plants inoculated with *H. mesophaeum*, *L. bicolor*, *S. pseudobrevipes* and the mixture of the three ECM species, respectively . Meanwhile, ECM colonization in non-inoculated plants was 19 and 22% for *P. greggii* and *P. pseudostrobis*, respectively . The morphotype analysis revealed that ECM colonization according to the inoculated species ranged from 15 to 69% in *P. greggii* and from 41 to 89% in *P. pseudostrobis* . Despite the fact that seedling transplanting was made at

the end of the rainy season, the percentage of survival was up to 100% , for all treatments 92 and 112 days after transplanting . In contrast 170 and 262 days after transplanting, during dry season, plant survival decreased distinctly compared with the inoculated edible ECM fungi . In general terms, the highest percentage of survival was observed in plants inoculated with the combination of three ECM fungi . Plants inoculated with either *S. pseudobrevipes* or *L. bicolor* presented higher survival percentages than those inoculated with *H. mesophaeum* or non-inoculated (Table 3) . It has been considered that some ECM fungi can confer drought tolerance to their associated hosts . In the case of *S. pseudobrevipes* such probable tolerance can be induced by the presence of abundant rhizomorphs which can dramatically, increase the absorption area (Duddridge *et al.*, 1980) .

Discussion

Increments in plant biomass had been documented as a result of inoculation with genera of some of the ECM mushrooms studied in our work . For example,

Table 2 Dry weight and nutrient contents of two pine species inoculated or no with three edible ectomycorrhizal mushrooms, 240 days after sowing under greenhouse conditions

Variable and treatments	Plant species and parts of the plant					
	<i>Pinus greggii</i>			<i>Pinus pseudostrobus</i>		
	Shoot	Root	Total	Shoot	Root	Total
Dry weight						
Nip	314.9 c	190.5 d	505.4 c	291.5 c	137.3 c	428.8 b
piHm	770.8 a	276.2 b	1 052.1 a	540.5 a	218.5 a	759.0 a
piLb	592.5 b	259.8 bc	852.3 b	413.7 ab	160.9 b	574.7 ab
piSp	612.8 b	248.6 cd	861.8 b	389.5 b	203.6 a	618.1 ab
pi LHS	735.3 a	296.6 a	1 026.8 a	490.6 a	234.0 a	724.6 a
N content						
sNip	2.4 c	1.7 c	4.1 c	3.0 c	0.9 c	3.9 c
piHm	9.5 a	2.7 b	12.2 a	4.6 b	1.8 b	6.4 bc
piLb	9.4 a	2.8 b	12.2 a	6.4 a	2.1 ab	8.5 a
piSp	5.8 b	2.0 c	7.8 b	5.0 b	1.8 b	6.8 b
pi LHS	8.8 a	3.4 a	12.2 a	5.8 a	2.5 a	8.3 a
P contents						
Nip	0.31 b	0.27 b	0.58 d	0.25 c	0.13 c	0.38 c
piHm	0.93 a	0.47 a	1.41 a	0.63 a	0.31 ab	0.94 a
piLb	0.70 a	0.40 a	1.11 b	0.65 a	0.30 ab	0.95 a
piSp	0.63 a	0.19 c	0.82 c	0.45 b	0.23 b	0.68 b
pi LHS	0.72 a	0.39 a	1.11 b	0.60 ab	0.38 a	0.98 a

Note: Nip = non-inoculated plants; piHm = plants inoculated with *Hebeloma mesophaeum*; piLb = plants inoculated with *Laccaria bicolor*; piSp = plants inoculated with *Suillus pseudobrevipes*; piLHS = plants inoculated with *L. bicolor*, *H. mesophaeum* and *S. pseudobrevipes*. Numbers with different letters in each part of the plant, in each variable, are different according to Tukey test ($P = 0.05$). n = 20.

Table 3 Percentage of survival of *Pinus greggii* plants inoculated with three edible ectomycorrhizal fungi and non-inoculated plants, during 9 months after transplanting

Treatments	Days after transplanting			
	92	112	170	262
Non-inoculated plants	100	100	44	19
Plants inoculated with <i>Hebeloma mesophaeum</i>	100	100	90	10
Plants inoculated with <i>Laccaria bicolor</i>	100	100	100	50
Plants inoculated with <i>Suillus pseudobrevipes</i>	100	100	93	57
Plants inoculated with LHS *	100	100	100	100

* a mixture of with *L. bicolor*, *H. mesophaeum* and *S. pseudobrevipes*. n = 16

Sudhakara-Reddy and Natarajan (1997) reported increments of 218% and 182% in shoot and root dry weight, respectively, as a result of inoculation with *Laccaria laccata*, relative to non-inoculated *Pinus patula* plants, twelve months after inoculation in sterilized soil. Additionally, several studies have found that simultaneous inoculation with different ECM mushrooms can produce larger increments in biomass in inoculated plants than inoculation with a single species (Parladé and Ivarez, 1993; Sudhakara-Reddy and Natarajan, 1997). Sudhakara-Reddy and Natarajan (1997) inoculated *Pinus patula* with *Laccaria laccata* and *Thelephora terrestris* and found a synergetic effect in shoot dry weight as a result of simultaneous inoculation with these species. However, in our study simultaneous in-

oculation with the three ECM species studied did not produce a synergistic effect, even though a generally beneficial effect was maintained. Several authors have reported that inoculation with ECM mushrooms causes an increment in the total nutrient content of both temperate and tropical trees and bushes, mainly that of N and P (Turjaman *et al.*, 2006; Nara, 2006; Tibbett and Sanders, 2002). In our case we used early-stage ECM species: *Laccaria*, *Hebeloma* and *Suillus* (Mason *et al.*, 1983). Usually early or intermediate stage ECM species (as opposed to late-stage species) require only small amounts of carbon from their hosts and low concentrations of nitrogen and phosphorus (Gibson and Deacon, 1990; Bergemann and Miller, 2002). These species usually produce increases in plant biomass in

the greenhouse or nursery probably because of their preference for mineral sources of N and P (Rincón *et al.*, 2001; Sudhakara-Reddy and Natarajan, 1997; Chu-Chou and Grace, 1985). It was reported that ECM symbiosis can cost 7 to 30% of the C fixed by the plants (Leake *et al.*, 2004). Although this cost may be considered high, once the mycelial networks are established, there is the possibility of substantial translocation of N and P (Pérez-Moreno and Read, 2000, 2001a, b); thus, ECM symbiosis in general terms is considered mutuality (Read and Pérez-Moreno, 2003). However, our inoculation experiments showed that ground pileus can be used as a successful source of ECM inoculums for pines. Studies on the other species of ECM edible fungi and plants would be highly desirable.

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References:

- Agerer R, 1991. Characterization of ectomycorrhiza [J]. *Methods Microbiol.*, 23: 25—73
- Bergemann SE, Miller SL, 2002. Size, distribution, and persistence of genets in local populations of the late-stage ectomycorrhizal basidiomycete, *Russula brevipes* [J]. *New Phytologist*, 156: 313—320
- Bremner JM, 1965. Total nitrogen [A]. In: Black CA (ed) *Methods of soil analysis Part 2*, Agronomy 9 [M]. Madison WI: American Society of Agronomy, 1149—1178
- Chu-Chou M, Grace LJ, 1985. Comparative efficiency of the mycorrhizal fungi *Laccaria laccata*, *Hebeloma crustuliniforme* and *Rhizopogon* species on growth of radiata pine seedlings [J]. *New Zealand Journal of Botany*, 23: 417—424
- Conabio, 1998. La diversidad biológica de México: estudio de un país. México: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO)
- Duddridge JA, Malibari A, Read DJ, 1980. Structure and function of mycorrhizal rhizomorphs with special reference to their role in water transport [J]. *Nature*, 287: 834—836
- Gibson F, Deacon JW, 1990. Establishment of ectomycorrhizas in aseptic culture: Effects of glucose, nitrogen and phosphorus in relation to successions [J]. *Mycol Res*, 94: 166—172
- Guzmán G, 1997. Los nombres de los hongos y lo relacionado con ellos en América Latina. Xalapa, México: Instituto de Ecología
- Index Fungorum, 2008. www.indexfungorum.org [OL]
- Izta-Popo National Park, 2007. www.iztapopo.conanp.gob.mx [OL]
- Leake J, Johnson D, Donnelly D *et al.*, 2004. Networks of power and influence: the role of mycorrhizal mycelium in controlling plant communities and agroecosystem functioning [J]. *Canadian Journal of Botany*, 82: 1016—1045
- Mason PA, Wilson J, Last FT, 1983. The concept of succession in relation to spread of sheathing mycorrhizal fungi on inoculated tree seedlings growing in unsterile soils [J]. *Plant and Soil*, 71: 247—256
- Nara K, 2006. Ectomycorrhizal networks and seedling establishment during early primary succession [J]. *New Phytologist*, 169: 169—178
- Olsen SR, Cole CV, Cantable FS *et al.*, 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate, circular 939. Washington, DC: US Department of Agriculture
- Parladé J, Ivarez IF, 1993. Coinoculation of aseptically grown Douglas fir with pairs of ectomycorrhizal fungi [J]. *Mycorrhiza*, 3: 93—96
- Pérez-Moreno J, Read DJ, 2000. Mobilization and transfer of nutrients from litter to tree seedlings via the vegetative mycelium of ectomycorrhizal plant [J]. *New Phytologist*, 145: 301—309
- Pérez-Moreno J, Read DJ, 2001a. Exploitation of pollen by mycorrhizal mycelial systems with special reference to nutrient recycling in boreal forests [J]. *Proceedings of the Royal Society of London*, 268: 1329—1335
- Pérez-Moreno J, Read DJ, 2001b. Nutrient transfer from soil nematodes to plants: A direct pathway provided by the mycorrhizal mycelial network [J]. *Plant Cell Environment*, 24: 1219—1226
- Perry J, 1991. The pines of Mexico and Central America [M]. Portland, Oregon: Timber Press
- Read DJ, Pérez-Moreno J, 2003. Mycorrhizas and nutrient cycling in ecosystems - a journey towards relevance [J]. *New Phytologist*, 157: 475—492
- Rincón A, Ivarez IF, Pera J, 2001. Inoculation of containerized *Pinus pinea* L. seedlings with seven ectomycorrhizal fungi [J]. *Mycorrhiza*, 11: 265—271
- SAS Institute, 1999. SAS User's Guide, ver. 8.0. Cary, NC: SAS Institute Inc
- Sudhakara-Reddy M, Natarajan K, 1997. Coinoculation efficacy of ectomycorrhizal fungi on *Pinus patula* seedlings in a nursery [J]. *Mycorrhiza*, 7: 133—138
- Tibbett M, Sanders FE, 2002. Ectomycorrhizal symbiosis can enhance plant nutrition through improved access to discrete organic nutrient patches of high resource quality [J]. *Annals of Botany*, 89: 783—789
- Turjaman M, Tamai Y, Segah H *et al.*, 2006. Increase in early growth and nutrient uptake of *Zorrea seminis* seedlings inoculated with two ectomycorrhizal fungi [J]. *Journal of Tropical Forest Science*, 18: 243—249
- Valencia AS, 2004. Diversidad del género *Quercus* (Fagaceae) en México [J]. *Boletín de la Sociedad Botánica de México*, 75: 33—53
- Villarreal L, Pérez-Moreno J, 1989. Los hongos comestibles silvestres de México, un enfoque integral [J]. *Micología Neotropical Aplicada*, 2: 77—114